

DSS Receiving System Saturation at High Signal Levels

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A loss of telemetry data from the Lunar Module occurred at DSS 14 during the Apollo 16 mission. This was caused by saturation of the first mixer in the DSS 14 receiving system by a very strong Command Module signal. Tests have been conducted to determine the saturation characteristics of the major components of the DSS receiving system. The problem will be avoided during the Apollo 17 mission by using a lower-gain maser as prime, and by adding a pad following the high-gain backup maser.

I. Introduction

During the Apollo 16 mission, DSS 14 (the Goldstone Mars station, which is equipped with a 64-m-diameter antenna) experienced a loss of data from the Lunar Module (LM). This occurred while the LM was being tracked at 2282.5 MHz, with a signal level of approximately -118 dBm. The time of data loss coincided with the Command and Service Module (CSM) switching to its high-gain antenna, resulting in a CSM signal level of approximately -88 dBm at 2287.5 MHz at DSS 14.

The very high signal level from the CSM was believed to have caused saturation of some component in the DSS 14 receiving system. After the mission, tests were conducted to determine the precise location of the saturation phenomenon, and to develop means of preventing a similar problem during the Apollo 17 mission.

II. DSS 14 Receiving System Tests

There are several possible areas in the DSS 14 receiving system which could have saturated. Referring to Fig. 1, these are the maser, the post-amplifier, and the receiver first and second mixers. Tests were conducted to determine the saturation characteristics of each of these components. The testing was performed over a period of several weeks during the summer of 1972, as station time became available.

Various configurations were established for the tests to isolate the saturation contributions of the various system components. All tests were essentially identical, and consisted of measurement of receiving system noise temperature, followed by measurement of receiver automatic gain control (AGC) characteristics. AGC data measurements covered the range from -80 to -120 dBm, which included the suspected saturation region.

III. Test Results and Analysis

The results of the test series, given in Figs. 2-6, clearly show that the maser, the post-amplifier, and the first mixer all contribute to the saturation effect, with the first mixer being most significant. All of these tests used the Mod 3 maser, which has normally been used for Apollo support.

Figure 2 shows AGC curves in the normal (Apollo 16) configuration. These curves begin to deviate from perfect linearity near -105 dBm, and show nearly complete saturation at -90 dBm. It is a safe assumption that this nonlinearity is the explanation for the telemetry loss experienced during the Apollo 16 mission.

Figure 3 shows the same curves, with 20 dB additional attenuation introduced at attenuator A406. If the second mixer were saturating, a substantial improvement in performance could be expected in this configuration. Figure 3 shows no change, demonstrating that second mixer saturation is insignificant.

Figure 4 shows AGC curves with 20-dB attenuation added in front of the first mixer of receiver 1 (point 4 in Fig. 1). To compensate for this, 20 dB of attenuation was removed from A406, allowing the remainder of the receiver to operate at normal levels. No changes were made to receiver 2. The effect of the 20-dB pad is simply to operate the first mixer of receiver 1 at 20 dB below normal levels, while all other elements of the receiving system operate normally. It is clear that a substantial improvement has been made in the strong signal performance of receiver 1. There is still a departure from perfect linearity, but it is not nearly as severe as that evident in receiver 2. Figure 4 thus demonstrates that, while other elements of the system are also beginning to saturate, the first mixer is by far the most significant contributor.

Figure 5 was obtained with the 20-dB pad moved to point 5 in Fig. 1. This allows both the post-amplifier and first mixer to operate 20 dB below normal levels. The curve for receiver 1 is almost identical to that of Fig. 4, demonstrating that saturation of the post-amplifier is insignificant. The curve for receiver 2 has also straightened out and follows the same shape as that for receiver 1, as expected. (The receiver 2 curve of Fig. 5 is dis-

placed from that in the preceding figures. This is believed to be due to an error in setting up attenuator A406, which was not noticed until the test was completed.)

Figure 6 shows the receiver 1 curves of Figs. 2, 4, and 5 replotted on the same graph, along with a dashed line representing a completely linear system. This clearly shows the improvement to be obtained by introducing the 20-dB pad at the maser output. Curve 1, the normal (Apollo 16) configuration, has a pronounced knee near -95 dBm. Curves 2 and 3 show a much more gradual degradation. The difference between curves 2 and 3 is attributable to gain compression in the transistor post-amplifier. The offset between curve 1 and the other curves at low signal level is attributable to a calibration error between the added 20-dB pad and the compensating 20 dB subtracted from attenuator A406. The gradual curvature of curve 3 is typical of the saturation characteristics of a maser, and is doubtless due to gain compression in the maser itself.

System temperature measurements were also made. A zenith temperature of 24.1 K was measured in the normal configuration. Introducing the 20-dB pad before the first mixer raised this temperature to 24.7 K. Introducing the pad before the post-amplifier raised it to 27.5 K. Inasmuch as the Apollo configuration will normally be used with the antenna pointed at the 300 K lunar background, this increase in system temperature is insignificant and can safely be ignored.

IV. Conclusions and Preparation for Apollo 17

As shown in Figs. 5 and 6, there is still some gain compression evident above about -105 dBm with a 20-dB pad installed behind the Mod 3 maser. Whether this will be sufficient to cause problems for Apollo 17 cannot be determined from RF tests. Telemetry system tests, using simulated Apollo telemetry, will be conducted prior to Apollo 17 support to determine the precise levels at which trouble can be anticipated.

Gain compression in a maser is normally found when the maser output level approaches -40 dBm. Since the Mod 3 maser operates at about 50-dB gain, this can be expected in the area of -90 dBm received signal power, which is confirmed by Figs. 5 and 6. It would seem that the problem could be eliminated by simply reducing the gain of the maser. However, the design of the Mod 3

maser is such that its gain cannot be reduced in the field below about 48 dB. Insertion of attenuation ahead of the maser, while it would eliminate the saturation problem, is not an acceptable alternative since it would eliminate the gain advantage of the 64-m-diameter antenna.

There is another maser available at DSS 14, known as the Polarization Diversity S-Band (PDS) maser. This is R&D equipment which has not been used as the prime maser on previous Apollo missions. The PDS maser is capable of covering the full Apollo bandwidth, and it can be operated at a much lower gain than the Mod 3 maser. Characteristics of the PDS maser are given in

Ref. 1, which shows that it is capable of a 1-dB bandwidth of 32 MHz while operating at 27-dB gain.

Since the PDS maser operates with approximately 20 dB less gain than the Mod 3 maser, system performance with it should be about the same as that shown in Figs. 5 and 6, with the ordinates of these figures shifted by about 20 dB. This would indicate that linear operation can be extended to at least -80 to -85 dBm by use of the PDS maser.

Current planning calls for the PDS maser to be used as prime for Apollo 17, with the Mod 3 maser followed by a 20-dB attenuator available for backup.

Reference

1. Clauss, R., and Quinn R., "Low-Noise Receivers: Microwave Maser Development," *The Deep Space Network*, Space Programs Summary 37-58, Vol. II, pp. 50-52, Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1969.

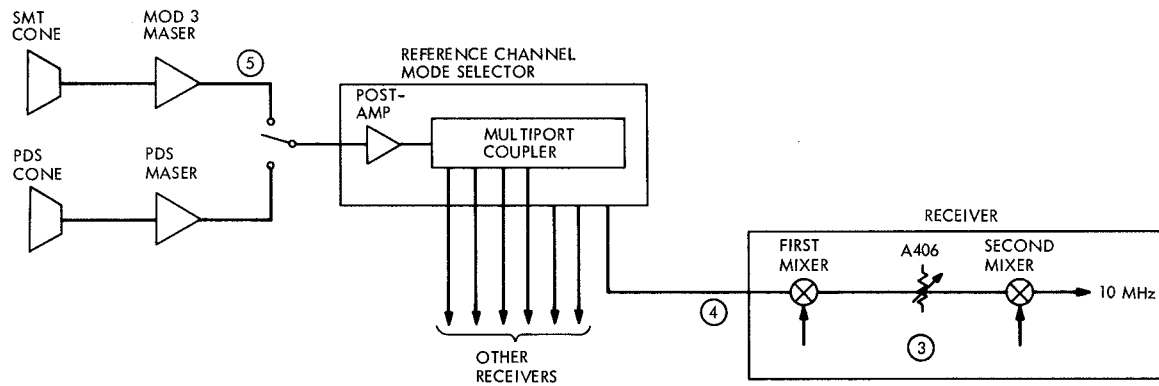


Fig. 1. DSS 14 receiving system, simplified block diagram

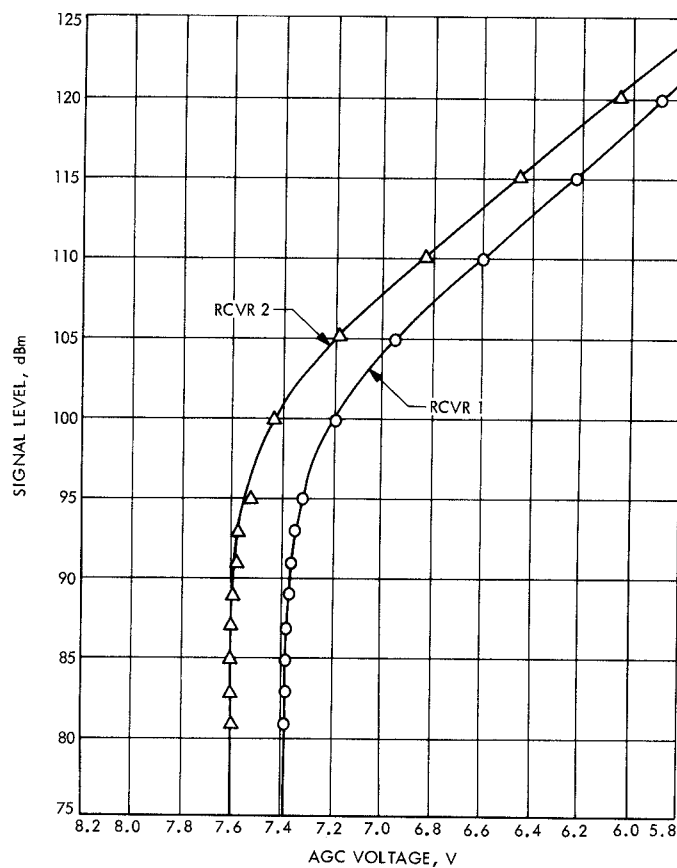


Fig. 2. AGC voltage vs. signal level—normal Apollo configuration (Mod 3 maser)

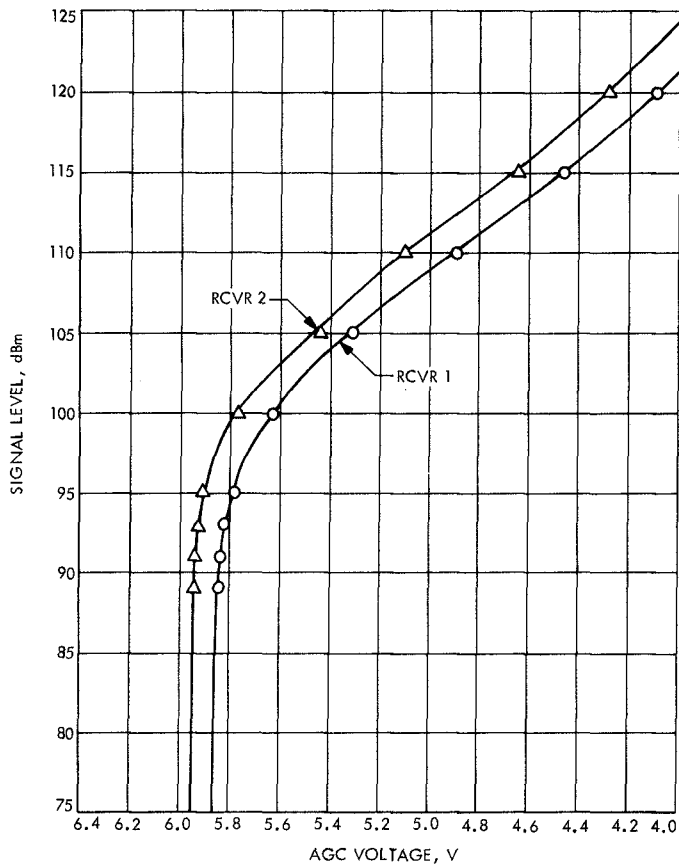


Fig. 3. AGC voltage vs. signal level—20-dB attenuation added to A406 (both receivers)

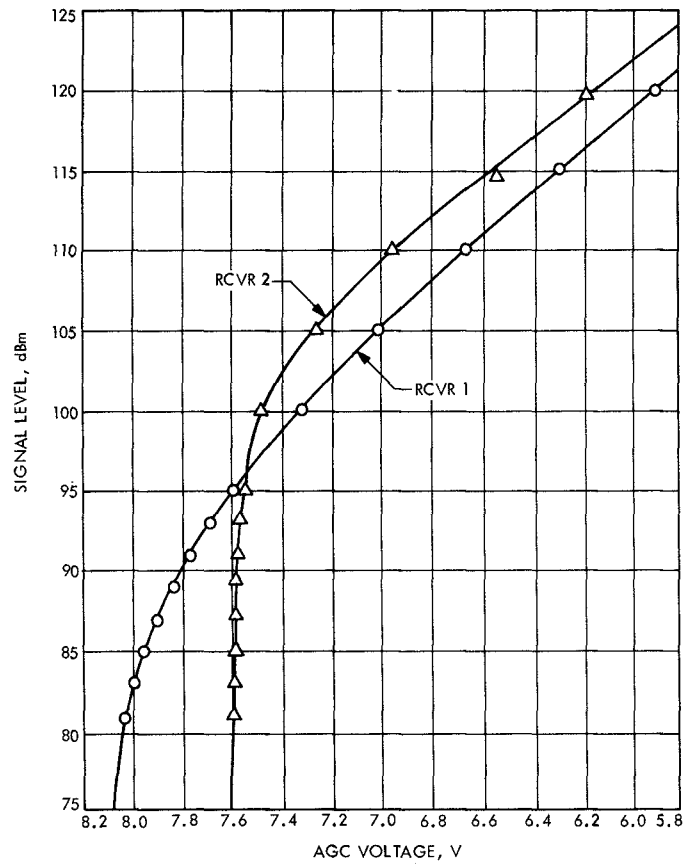


Fig. 4. AGC voltage vs. signal level—20-dB attenuation added before receiver 1 (receiver 2 normal)

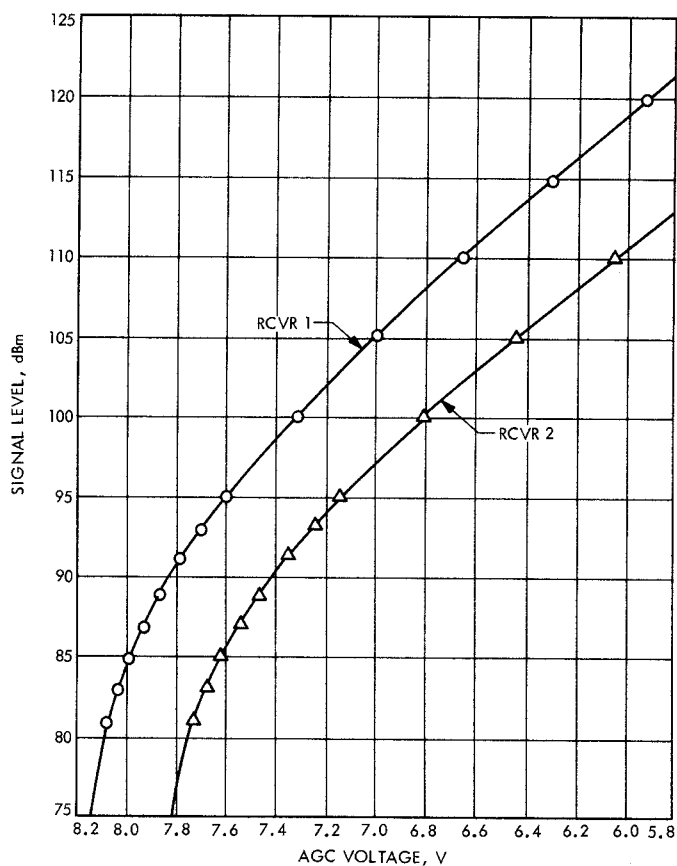


Fig. 5. AGC voltage vs. signal level—20-dB attenuation added after Mod 3 maser

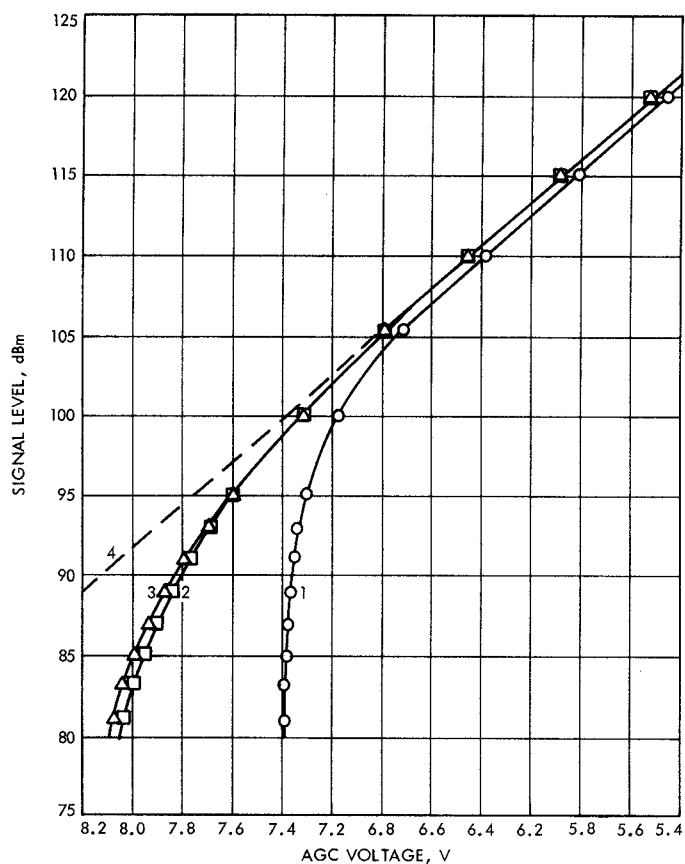


Fig. 6. AGC voltage vs. signal level—receiver 1 AGC (1) normal configuration, (2) 20-dB attenuation added before receiver first mixer, (3) 20-dB attenuation added before post-amplifier, (4) ideal configuration